

1     **PROCESS FOR THE MANUFACTURE OF COMPOSITE STRUCTURES**

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3     **BACKGROUND OF THE INVENTION**

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5     Government Rights

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7     (001) This invention was made under National Aeronautics and Space  
8     Administration contract No.: NRA8-30, dated 2002. Therefore the United  
9     States Government retains the rights granted under this contract.

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11    Field of the Invention

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13    (002) The invention relates to the field of composite structure fabrication  
14    procedures and, in particular, to a non-autoclave curing procedure for  
15    providing void free parts involving honeycomb sandwich.

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17    Description of Related Art

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19    (003) There are numerous processes for making a honeycomb core  
20    composite structure. For example, previously cured cover sheets made up of  
21    layers of filamentary material in a resin matrix can be directly bonded by an  
22    adhesive to the honeycomb core. However, it is desirable to use pre-  
23    impregnated filamentary material as cover sheets and bond to the core as the  
24    resin in the cover sheets cure. To insure a good bond between the cover  
25    sheets and core, a layer of adhesive is placed therebetween.

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27    (004) The actual process involves laying up a preform of the core with face  
28    cover sheets on a tool surface or mold. The preform is vacuum bagged. A  
29    vacuum is drawn from within the bag, and the assembly is heated to the curing

1 temperatures until the adhesive and resin are cured. Any trapped air or out-  
2 gassing from the resin and adhesive are drawn off because of the vacuum.

3 (005) The bagged preform is heated to curing temperatures as the vacuum  
4 draws out any gases from the resin and/or adhesive. Alternately, the vacuum-  
5 bagged preform can be placed in an autoclave wherein the pressure applied to  
6 the preform for consolidation purposes can be increased above atmospheric  
7 pressure. This generally reduces the possibility of voids and provides a more  
8 uniform cover sheets. However, autoclaves are expensive.

9  
10 (006) Thus, it is a primary object of the invention to provide a process for  
11 producing high quality honeycomb sandwich structures.

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13 (007) It is another primary object of the invention to provide a process for  
14 producing honeycomb core structures without the use of an autoclave.

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16 (008) It is a further object of the invention to provide a process for producing  
17 honeycomb core structures without the use of an autoclave, but providing  
18 equal quality.

## 19 20 **SUMMARY OF THE INVENTION**

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22 (010) The invention is a process for making a composite structure having a  
23 honeycomb core and face sheets using vacuum bagging techniques without  
24 the use of an autoclave. In detail, the process includes the following steps:

- 25 1. Separately de-bulking first and second covers made of multi-layers of  
26 filamentary material sheets pre-impregnated with a resin having a first curing  
27 temperature:
- 28 2. Forming a preform sandwich assembly by placing the first cover sheets on a  
29 mold surface; placing a first layer of adhesive on the first cover, the first layer

1 of adhesive having a second curing temperature less than the first curing  
2 temperature of the first cover sheets; positioning a honeycomb core  
3 material over said first layer of adhesive; placing a second layer of adhesive  
4 on the honeycomb core; and placing the second cover on top of the second  
5 layer of adhesive core, said second layer of adhesive having a second curing  
6 temperature less than the first curing temperature for the cover sheets;

7 3. Vacuum bagging the assembly;

8 4. Drawing a vacuum from within said vacuum bag;

9 5. Initially heating the assembly at a heating rate of between  $0.5 \pm 0.1$  degree  
10 and  $1.5 \pm 0.1$  degrees Fahrenheit per minute until the gel temperature of said  
11 adhesive is reached;

12 6. Holding the temperature at the gel temperature until the layer of adhesive  
13 has 70% cured;

14 7. Raising the temperature to the first curing temperature of the fiber  
15 reinforced resin; and

16 8. Maintaining the temperature at the first curing temperature until the resin  
17 has cured.

18 The above process is capable of forming composite sandwich structures  
19 having a quality equal to those fabricated by use of an autoclave. In  
20 addition, it does not require that the cover sheets be previously cured.

21  
22 (011) The novel features, which are believed to be characteristic of the  
23 invention, both as to its organization and method of operation, together with  
24 further objects and advantages thereof, will be better understood from the  
25 following description in connection with the accompanying drawings in which  
26 the presently preferred embodiment of the invention is illustrated by way of  
27 example. It is to be expressly understood, however, that the drawings are for  
28 purposes of illustration and description only and are not intended as a  
29 definition of the limits of the invention.

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## 2 **BRIEF DESCRIPTION OF THE DRAWINGS**

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4 (012) Figure 1 is cross-sectional view of a completed composite structure  
5 comprising a honeycomb core and cover sheets made of filamentary material  
6 in a resin matrix made by the subject process.

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8 (013) Figure 2 is a cross-sectional view of a tool use to de-bulk the fiber-  
9 reinforced cover sheets prior to curing.

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11 (014) Figure 3 is a cross-sectional view of a typical vacuum bagging stack-up  
12 used for making the composite structures by the subject process.

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14 (015) Figure 4 is a cross-sectional view of the apparatus shown in Figure 3

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## 17 **DESCRIPTION OF THE PREFERRED EMBODIMENT**

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19 (016) Referring to Figure 1, the process is primarily used to make composite  
20 sandwich structures 10 comprising a honeycomb core 11, with cover sheets  
21 12 and 14 made of layers of filamentary material in a pre-impregnated resin  
22 matrix bonded to the core by layers of adhesive 15 and 16, respectively. The  
23 filamentary layers can be made from unidirectional layers stacked at various  
24 angles such as 0, 45 and 90 degrees or a combination of angles. The  
25 composition of layers will depend upon the particular application. For handling  
26 purposes, the individual layers of filamentary are pre-impregnated with a resin  
27 and partially cured into pre- impregnated tapes. In this state, particularly if  
28 stored at low temperature, they have a significant shelf life. However, when

1 assembled into a cover sheet, they must be de-bulked prior to curing of the  
2 resin to insure that the final structure is free of voids.

3  
4 (017) Thus, the individual plies or stacks of plies for the cover sheets,  
5 indicated by numerals 12A and 14A, prior to the curing process are individually  
6 de-bulked in the apparatus 20 shown in Figure 2. For example, cover sheet  
7 14A is place on a tool 22, covered with an impermeable cover 24, which is  
8 sealed to the tool sealing tape 26, typically chromate tape. A vacuum line 27 is  
9 provided so that a vacuum can be drawn. This will cause an entrapped air or  
10 gases to be withdrawn from the cover 14A. De-bulking process details will  
11 vary, but may include vacuum de-bulking of individual plies or stacks of plies,  
12 ultrasonic lamination, or warm or hot de-bulks.

13  
14 (018) Referring now to Figures 3 and 4, the apparatus, generally indicated by  
15 numeral 30, includes a tool or mold 32 having a smooth surface 34. A layer of  
16 porous separator cloth 36, having a thickness of 0.005-inch, is placed on the  
17 surface 34. A suitable separator cloth 36 is Armalon, manufactured by the  
18 Richmond Company, Norwalk, California. The fiber-reinforced cover sheet 14A  
19 is placed over the cloth 36. An uncured sheet 16A of adhesive is placed over  
20 the cover sheet 14A; A honeycomb core 11 is then placed over the sheet 16A  
21 of adhesive. An uncured sheet 15A of adhesive is placed over the  
22 honeycomb core. The then the cover sheet 12A is placed over the sheet 15A  
23 of adhesive finally forming a composite sandwich structure preform 10A. A  
24 second sheet of separator cloth 38 is placed over the cover sheet 12A. An  
25 aluminum or cured composite caul plate 40, having a thickness of 0.25 inch is  
26 positioned there over.

27  
28 (019) Placed about the periphery of the preform 10A, is a silicone rubber dam  
29 42 sealed to the surface 34 by double-sided tape 44. A suitable silicon rubber

1 dam material is supplied by Airtech International Incorporated. A suitable tape  
2 44 is manufactured by Fralock Company, Canoga Park, California. The gap  
3 46 between the dam 42 and preform 10 should be less than 0.06 inch. A  
4 0.001 or 0.003-inch thick non-porous sheet 48 of material is positioned over  
5 the caul plate 40 and preform 10A and sealed to dam 42 by a second layer of  
6 double sided tape 50. A suitable sheet 48 is A-4000 Non-porous Armalon  
7 manufactured by Airtech International Incorporated, Huntington Beach,  
8 California. However, fiberglass inserts 52 are positioned on top of the dam 42  
9 creating flow paths there across. Strips of tape 54 are positioned between the  
10 fiber glass inserts 52 extend from the sheet 48 to the surface 34 of the tool 32,  
11 thus further securing the sheet 48 to the dam 42. A suitable fiberglass insert  
12 52 is No.: 181-fiberglass 0.014 inch thick. A suitable tape 54 is 0.002 inch  
13 thick Flashbreaker Tape, manufactured by Airtech International Incorporated.

14

15 (020) Positioned over the sheet 48 and dam 42 is a layer or layers 56 of  
16 fiberglass breather cloth (0.014 inch per ply). For example, 2-181 fiberglass  
17 manufactured by Richmond Company. A sheet 58 of 0.126-inch thick  
18 polyester material is positioned over the layers 56. Finally, a vacuum bag 60 is  
19 positioned over the sheet 58 and sealed to the surface 34 by means of  
20 vacuum bag sealed tape 62. Preferably the vacuum bag material is 0.003-  
21 inch thick nylon material obtainable from Airtech International Incorporated.  
22 The tape 62 is GS 100 also manufactured by Airtech International  
23 Incorporated. Vacuum port lines 64 extend to the tape 62 and are coupled to  
24 vacuum pumps (not shown). These sheets are needed to make an air tight  
25 vacuum bag without leaving impressions called "mark-offs" in the composites.  
26 The lower sheets are used to contain the resin of the prepreg resin flow is  
27 restricted to within the sheets. The dams prevent the edges from being  
28 pinched off, crushed or made thinner than the surrounding materials. The  
29 completed assembly is typical of that used to make composite structures and

1 there are variations both as to the selection of materials, thickness thereof and  
2 the sources.

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4 (021) With the assembly illustrated in Figure 3 and 4, is then place in an oven  
5 and the following cure cycle is followed.

6 1. A vacuum is drawn through the ports 64, which causes the vacuum bag  
7 60 to contract about compressing the sheets 48, 56, 58 about the caul plate  
8 40 and preform 10A. The vacuum level should be at least 25 inches of  
9 mercury.

10 2. The temperature is slowly raised at a rate of 0.5 to 2 degrees per  
11 minute; preferably 1 degree per minute until an intermediate temperature is  
12 reached and held to provide approximately 70 percent cure of the sheets 15A  
13 and 16A of adhesive.

14 3. The intermediate temperature is maintained for a period of  
15 approximately one-hour or until the sheets 15A or 16A have reached the gel  
16 state. This minimizes the formation of bubbles in the sheets of adhesive.

17 4. The temperature is then raised to and held for the appropriate time at  
18 the curing temperature of the first resin in the fiber-reinforced cover sheets  
19 14A and 14B until the sheets have cured. At this point the preform 10A had  
20 been transformed into the completed composite sandwich structure 10.

21 Thereafter, the assembly is removed from the oven, and after the assembly  
22 has cooled sufficiently, the composite structure 10 can be removed from the  
23 tool.

24

25 (022) Numerous structures have been fabricated using this procedure. For  
26 example:

27 1. Cover 12 and 14 sheets made 8 to 128 layers of layers of Part no.  
28 IM7/977-2 epoxy pre-impregnated graphite fibers manufactured by Cytec  
29 Corporation, Anaheim.

- 1     2. Kevlar® paper honeycomb core 11, Part HK362-04896 manufactured by  
2         M. C. Gill Company, El Monte, California  
3     3. Sheets 15 and 16 of adhesive were EA9696AL manufactured by Loctite,  
4         Bay Point, California.

5     The process has produced structures equal in quality to autoclave produced  
6     structures wherein the cover sheets were pre-consolidated and cured.

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8     (023) While the invention has been described with reference to a particular  
9     embodiment, it should be understood that the embodiment is merely  
10    illustrative, as there are numerous variations and modifications, which may be  
11    made by those skilled in the art. Thus, the invention is to be construed as  
12    being limited only by the spirit and scope of the appended claims.

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#### 14     **INDUSTRIAL APPLICABILITY**

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16    (024) The invention has applicability to any industry using composite  
17    structures, in particular aircraft manufacturing industries.